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GEOMORPHOLOGY

OF THE

SOUTHERN APPALACHIANS

C. WILLARD HAYES AND MARIUS R. CAMPBELL.

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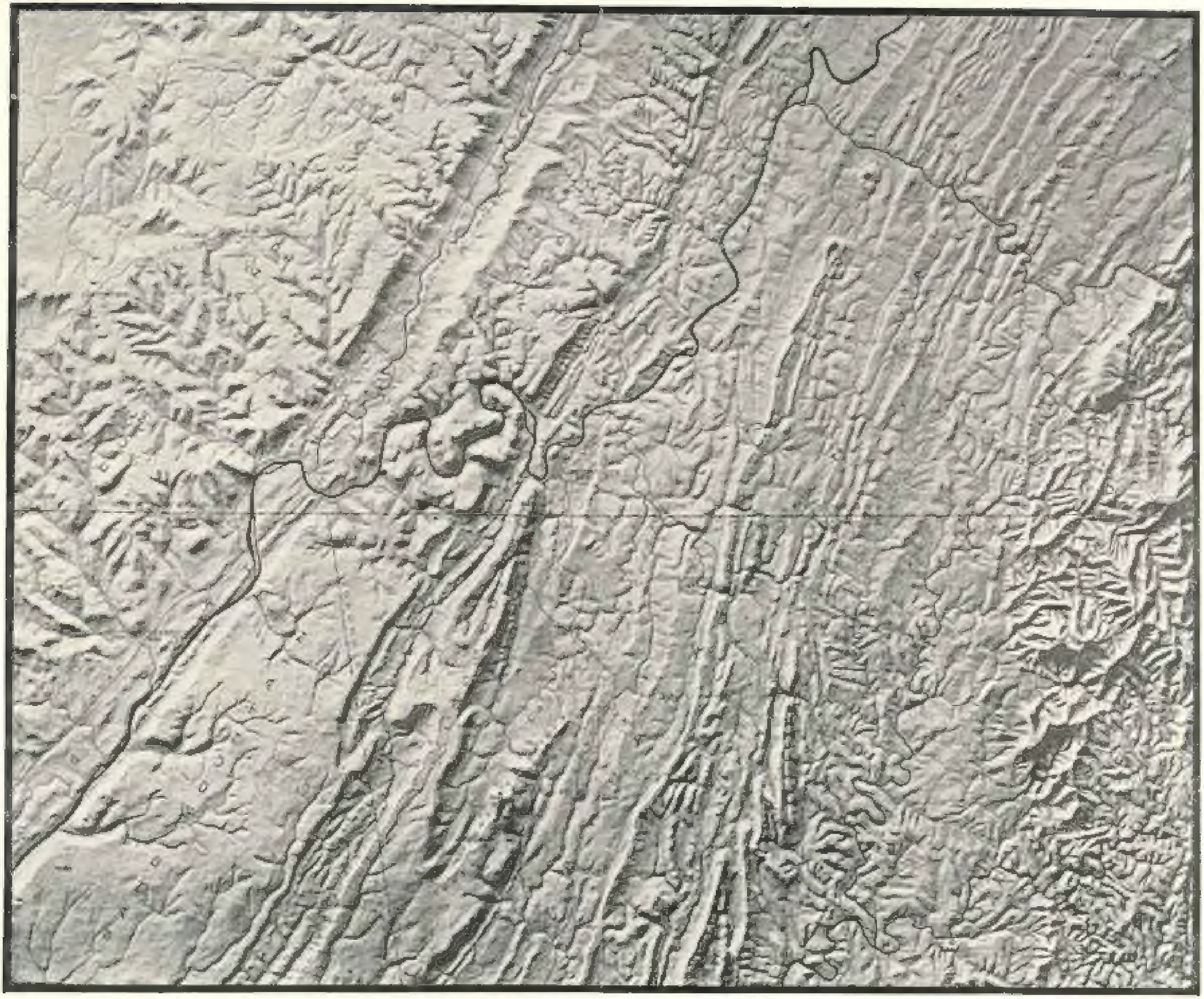

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RELIEF MAP OF THE CHATTANOOGA DISTRICT.

Horizontal scale 16 miles to 1 inch.

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GEOMORPHOLOGY OF THE SOUTHERN APPALACHIANS*

BY

CHARLES WILLARD HAYES AND MARIUS R CAMPBELL

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INTRODUCTION.

REVIEW OF PREVIOUS WORK.

The post-Paleozoic history of the Appalachian province has, until recent years, been known only in the most general terms. That the region has been a land area since the close of Carboniferous time was known, and it was assumed that, in common with other land areas, it had been repeatedly elevated and depressed, yet the extent and character of these movements, in the interior at least, were not only unknown, but no data were supposed to exist by which they could be measured. Along the

margin of the province the subsidences are recorded in the sediments deposited as the sea transgressed upon the land, and in some cases the amount of subsequent uplift is indicated by the recession of overlying deposits. In so far as these oscillations have been determined from sedimentary deposits, each transgression of the sea was regarded as marking a continental depression, and each recession a continental uplift. Within the past few years, however, a complete revolution has been effected in the interpretation of the post-Paleozoic history of this region. Through the work of a few pioneers in this field the number and character of the principal oscillations and their position in geologic time are now fairly well known.

The first systematic application of the new methods of research was made by Mclne in the middle Atlantic slope. In 1885, in a paper on the geology of Chesapeake bay,* he pointed out the methods pursued and the importance of utilizing topographic forms resulting from degradation, as well as the complementary sedimentary deposits in interpreting geologic history. In 1888† he more definitely correlated the principal oscillations with the sedimentary deposits, thus fixing their position in geologic time, and in a subsequent paper‡ he made the very important generalization that all elevations have been accompanied by seaward tilting of the land, and that along certain axes the oscillations have reached a maximum amount, while along others both elevation and depression have been at a minimum.

Davis§ published the results of his studies on the geomorphology of the middle and north Atlantic slope shortly after the

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* The Geology of the Head of Chesapeake Bay, by W J McGee: Seventh Annual Report U. S. Geological Survey, 1885, pp. 545–646.

† Three Formations of the middle Atlantic Slope, by W J McGee: Am. Jour. Sci., vol. xxxv, 1888.

‡ The Lafayette Formation, by W J McGee: Twelfth Annual Report U. S. Geological Survey, 1890, pp. 353–521.

Geology of Washington and Victoria, by W J McGee: Compte Rendu de la Congrès Géologique International, 5th Session, Washington, 1891, pp. 219–251.

§ The Rivers and Valleys of Pennsylvania, by W. M. Davis: Nat. Geog. Mag., vol. 1, 1889, pp. 183–253.

The geographic Development of northern New Jersey, by W. M. Davis and J. W. Wood: Proc. Boston Soc. Nat. Hist., vol. xxiv, 1889, pp. 365–423.

The Rivers of northern New Jersey, by W. M. Davis: Nat. Geog. Mag., vol. ii, 1890, pp. 81–110.

appearance of the first two papers above cited. He has carried his observations somewhat further toward the interior and describes two well marked baselevel peneplains in eastern Pennsylvania, New Jersey and portions of New England, the formation of which, he ascribes to long continued erosion in Cretaceous and Tertiary time. A general eastward tilting of the peneplain is described, but no attempt is made to locate the axes of their deformations. In 1889 Davis published a more comprehensive paper,† bringing in review all previous publications on the baselevels of the Atlantic slope and discussing the probable continuation of the peneplains, found in the northern portion southward over the whole of the Appalachian province.

Thus the broad outlines and to some extent the details of post-Paleozoic history of the Atlantic slope and Mississippi embayment have been determined, but for most of the interior the details are still wanting. The present paper is an attempt to supply in some measure this deficiency.

THE PROVINCE DEFINED

For present purposes the southern Appalachian province is regarded as embracing the region south of the Ohio and Potomac rivers and limited toward the east, south, and west by the Cretaceous and the later formations of the coastal plain and Mississippi embayment. One or both of the present writers are personally familiar with the greater part of this region, and many observations made in connection with the work of the Appalachian division of the United States Geological Survey are here for the first time brought together. The location of the region is exceptionally favorable for the study of its geomorphology. Surrounded on three sides by Mesozoic and later deposits, the relations of land and water which prevailed during post-Paleozoic time are fairly well determined. The character of the sediments serves to establish correlations between them and their corresponding erosion features. The intersection of erosion planes with deposits of known age serves to fix the date of each erosion period within narrow limits. Finally, the absence of glaciation and glacial deposits renders the interpretation of topographic forms and of drainage systems much easier than in regions

† The geologic Dates of Origin of certain topographic Forms on the Atlantic Slope of the United States, by W. M. Davis: Bull. Geol. Soc. Am., vol. II, 1891, pp. 545–586.

whose glaciation has interfered with their normal development or masked their unglaciated form.

THE PROBLEMS AND THE DATA.

Since the southern Appalachian province, as above defined, has stood above sealevel throughout the whole of the period whose history is under consideration, that history must be read in the topographic forms developed during the process of subaerial degradation and in the adjustments of drainage to changing conditions.

The fundamental conception in the interpretation of the history of a region from its topographic forms, is the *peneplain of erosion*. The formation of a general baselevel peneplain implies the long continuance of certain well defined conditions, so that wherever the presence of such a peneplain can be established the former existence of these conditions may be safely inferred; also it can be formed only once scoured; hence by contouring the present remnants of a baseleved peneplain the contour at any point represents very nearly the algebraic sum of all changes in altitude which that portion of the plain has suffered.

In the southern Appalachian province the traces of less perfectly preserved remnants of two baseleved peneplains have been mapped and their deformations represented by contours; the conditions implied by these baselevels have been inferred; their probable correlations with the contemporaneous sedimentary deposits indicated; and finally the development of the drainage has been traced through a complex series of adjustments upon the repeatedly deformed surface to the present relative location.

Part I—Physiographic Development.

A. Description of Topographic Features in the Province.

The southern Appalachian province has certain topographic features common throughout its entire extent. They are so modified by local conditions that their identity in different portions of the province would scarcely be recognized by the casual observer, but to the student of geomorphology they stand out as the most prominent feature of the landscape and he reads from them many chapters in the history of the province during post-Paleozoic time. With our present information we are able to classify these topographic forms and to trace with considerable

certainty the more prominent features over the greater portion of the province. In some portions lack of data prevents the identification and correlation of these forms, but it is probable that further study will show the same features there as in the better known regions. The identity and practical continuity of certain topographic forms have been clearly proven through the major portion of the southern Appalachian province, and by other writers across Pennsylvania, New Jersey and the greater portion of New England, so that the conditions and agencies which produced them must have prevailed uniformly over wide areas.

In addition to these principal topographic forms, there are many minor features which doubtless record brief and local conditions, but in most cases the data at hand are not sufficient for their determination.

Inferences from the observed topographic forms back to the conditions under which they were produced necessarily involve elements of uncertainty, and the writers are fully aware that some of their conclusions are open to question and may be modified by further study.

The classification of the main topographic features of the province is as follows:

1. Elevations standing above the Cretaceous peneplain.
2. Deformed Cretaceous peneplain.
3. Intermediate erosion slopes.
4. Deformed Tertiary peneplain.
5. Post-Tertiary erosion slopes.

Of these five classes the two baseleveled peneplains are most important to the student of geomorphology, for they render it possible to interpret the meaning of the other topographic features and to fix the dates of their origin in geologic time.

ELEVATIONS STANDING ABOVE THE CRETACEOUS PENEPLAIN.

The oldest topographic forms found in the southern Appalachian province are those portions of the land which were not reduced to baselevel during the long period of Cretaceous erosion. These summits may possibly mark the position of a still earlier baseleveled peneplain; but if so, the remnants are so few that we are unable to reconstruct the ancient plain. Protected by a favorable location with reference to drainage lines or composed of exceptionally durable rocks, they stood during the formation of the Cretaceous peneplain in low relief above the

level surface and still remain as isolated peaks, ridges or mountain groups above the remnants of that plain. The distribution and relations of these remnants will be more easily understood after the Cretaceous peneplain has been described in detail, hence their consideration will be deferred and taken up under the physiography of the Cretaceous peneplain.

[illegible] PENEPLAIN

The oldest topographic feature that can be identified with certainty in this region is one which forms the base upon which all later history has been recorded, is a more or less perfectly preserved, bevelled peneplain. The reasons for assigning its formation to Cretaceous time are given in a later part of this report and its Cretaceous age may be assumed for the present. In addition, at earlier periods the surface of the province had been brought to base-level again and again, but subsequent erosion has so modified these earlier forms as to leave them unrecognizable.

Conditions of Development.—The conditions under which a plain of erosion will be formed and brought into stability of base-level and as these have been determined by geologists, the essential condition is that the relative positions of land and sea shall remain fixed for a period long enough to allow the agents of erosion to carry their work towards completion and reduce the surface of the land to or near the base-level of erosion.

During Cretaceous time the condition of stability prevailed in this region for the longest period of which we have any record in its history. For we hold it is a popular belief that the normal condition of the earth's crust is one of stability, the reverse is shown to be true of this region. Its history in post-Paleozoic time is a record of almost continuous orogenic movement—extremely slow, it is true, but quite sufficient in time allowed, capable of producing the greatest deformations with which we are acquainted.

During this period of exceptional quiet, erosion was in progress, for a time at least sufficient to wear down the land rapidly at first, when the land was high and the slopes steep, but at a rate growing gradually less as the gradient of the streams decreased and with it the capacity to carry off the waste of the land. As the gradient approached its lowest limit the mineral matter received from the land was almost wholly in solution. This process continued to reduce the land to base-level, first the soft and soluble

[illegible]

[illegible] have been removed [illegible]

[illegible]

[illegible]

The [illegible] described [illegible] French Broad, has been for a long time [illegible] the river [illegible] of the Great Smoky [illegible] by the [illegible] Tennessee [illegible] the Tennessee system [illegible] rivers [illegible] The altitudes of [illegible] but [illegible] the whole [illegible] westward. Thus [illegible] feet on the [illegible] Tennessee, [illegible] feet [illegible] The proportion of [illegible] and in [illegible] mountain valleys [illegible] with low [illegible] which [illegible] feet below [illegible] appears that the [illegible] later.

[illegible] French [illegible] strong [illegible]

[illegible] p. 26

[illegible]

[illegible] the present [illegible], while the present [illegible] seems to represent the former level [illegible] between the [illegible] monadnocks. In the plateau region south of the Tennessee [illegible] there is no [illegible] of [illegible] to be represented in the [illegible]. The peneplain in this portion of the province was [illegible] and in some others and [illegible] elevated [illegible] above the general level. [illegible] by the [illegible] of erosion [illegible].

[illegible]

One of the most important [illegible] considered in the present paper, in its bearing upon [illegible], is the [illegible] of the nature of the deformation [illegible] in the present attitude of the [illegible]. It is [illegible] these deformations have been [illegible] produced by [illegible] movements affecting comparatively narrow areas along certain well defined axes, [illegible] originally horizontal [illegible], [illegible] suggested by Willis,* uplifts which [illegible] the surface across the whole expanse of the [illegible] so that [illegible] activity has not [illegible] long [illegible] through [illegible] province.

[illegible] have been [illegible] by other [illegible], especially [illegible] and [illegible]. [illegible] Pennsylvania, New Jersey and [illegible] of New England [illegible] seaward, but [illegible] elevation [illegible] has been greatest at the [illegible] and [illegible] greatest in the interior, [illegible] a cumulative seaward [illegible]. The [illegible] of facts from which [illegible] clearly [illegible] the [illegible], [illegible] which will be more fully [illegible] on a subsequent page.

*Topography and [illegible] of the [illegible], Tennessee. By Bailey Willis. School of Mines Quarterly, vol. [illegible], 1887, p. [illegible].

In order to represent in as graphic a manner as possible the present form of the Cretaceous peneplain, a map showing contours on the deformed surface has been constructed [illegible] upon the best [illegible] assembled the available data derived from a careful comparison of the various known remnants of the plain within the province. The result appears on plate 5, and should be regarded by the writer as preliminary [illegible] the information at present obtainable. Although imperfect, the map is highly suggestive, and it is hoped that it may lead to the construction of similar maps for other [illegible] [illegible] [illegible]

sent widely different proportions of fact and hypothesis and hence differ in value. Through the southern part of the province the peneplain, as already described, is well preserved, and the map of this portion is based upon a large number of personal observations and may be considered fairly accurate. In some regions in the northern portion of the province only scanty remnants of the peneplain are found, and the evidence of its existence is so indefinite that while the present map is unsatisfactory it is doubtful if anything better can be constructed even with further field observations. Other portions are based upon a study of [illegible] topographic [illegible] profiles and verbal descriptions of topography, so that the results are correspondingly less satisfactory.

As already suggested, the deformations of the Cretaceous peneplain represented by the contour map (plate 5) are not the result of a single [illegible] nor of a single system of orogenic movements, but the [illegible] of several movements, both of elevation and depression, which have affected the region since the peneplain was formed. Not only have the movements been in opposite directions and at different periods, but the axes of maximum motion have not always been the same nor even parallel. They have intersected at various angles and the surface has been warped accordingly. The data are not sufficient for a map showing all the details and a description of the principal axes only will be

Longitudinal axes of deformation. — The [illegible] principal [illegible] are longitudinal axes, and, so far as known, these are axes of elevation alone, though depression of which no record is left may have taken place along them also. They are indicated by broken lines on plate 5 and marked by the letters *C D*, *E F* and *G H*.

These are lines of maximum elevation and they have had a predominant part in producing the present topography of the province. They coincide with the present mountains and in a general way form all the great structural features of the Appalachian valley.

Transverse axes of elevation.—In addition to the predominant longitudinal axes a number of subordinate transverse axes are recognizable, affecting the [illegible] and Cretaceous peneplains. In the central portion of the uplift the [illegible] not marked [illegible], giving a broader and more regular profile to the elevation than elsewhere. This is suggestive of a transverse line of uplift intersecting the longitudinal axes nearly at right angles. If this line be prolonged in both directions it is found to [illegible] and Cape Hatteras, both of which have been recognized as marking points of transverse elevation. As early as 1871 Shaler* described a transverse uplift which he concluded had produced the great projection of the coast line at Cape Hatteras. Later McGee has shown that this axis has been an important factor in determining the form of the coast and drainage, as is expressed by the deposits of the coastal plain. He considers it [illegible] axis of [illegible] during every geologic period since the Cretaceous.† If this line from Cape Hatteras to Cincinnati be continued across the Ohio river its direction will be found to coincide with that of the [illegible] northwestward [illegible] the Cincinnati arch which crosses Indiana to Chicago. Although, with the information at present available, it cannot be asserted that movement has taken place along the southeastern portion of the line except in post-Cretaceous time, the coincidence of the two axes suggests [illegible] that there was [illegible] movement in the Appalachian region during the uplift of the Cincinnati arch [illegible], and conversely, that north of the Ohio river may yet be found traces of post-Paleozoic movements corresponding to the later uplifts in the vicinity of Cape Hatteras. The probability of such contemporaneous movement is increased by the fact that in [illegible] northern portion of the

* On the Causes which have led to the Production of Cape Hatteras, by Professor N. S. Shaler: Proc. Bost. Soc. Nat. Hist., vol. xiv, pp. 110-12.

† The Lafayette formation, by W J McGee: 12th Annual Report U. S. Geological Survey, 1891, p. 463.

of the [illegible] and the Tertiary lowland, the peneplain was formed up to the base of the [illegible] escarpment and for [illegible] limestone [illegible] which [illegible] its border. In the [illegible] the formation of [illegible] from the stream [illegible] to [illegible] the [illegible] that [illegible] altitude of from 1, [illegible] to 1, [illegible] feet. There is a belt of [illegible] bordering the [illegible] west and extending [illegible] northward from [illegible] Alabama to the Kentucky-Tennessee line [illegible] were favorable for the [illegible] been favorable for the preservation of the [illegible]

Across Kentucky the [illegible] were similar to those of Tennessee, [illegible] the [illegible] and Mesozoic [illegible] were [illegible] and formed [illegible] more or less [illegible] the [illegible] variety of [illegible] the [illegible] be recognized [illegible] difficulty. The conditions [illegible] at present entirely [illegible] and the only [illegible] the present writer can offer is that [illegible] the two peneplains [illegible] approach each other [illegible] that direction until they practically coincide.

Along the south [illegible] margin of the province the elevation between the two peneplains [illegible] that the rocks are [illegible] exposed to [illegible] nearly the beginning of Cretaceous to [illegible] time, [illegible] poorly preserved [illegible] records of the past. In the Cretaceous [illegible] the Tertiary [illegible] is generally [illegible] although [illegible] deeply into its surface [illegible] of the rocks has [illegible] the least resistant [illegible] lower level [illegible] that at which the present streams of the region are flowing. [illegible] eastward, the vertical interval between the Cretaceous and Tertiary base [illegible] and in the vicinity of Atlanta [illegible] practically [illegible] so that the recognition of the two peneplains is almost impossible. [illegible] have [illegible] the old peneplains [illegible] the [illegible] of the [illegible] and Tallapoosa rivers [illegible] flow upon the surface of the [illegible] peneplain.

On the [illegible] eastern [illegible] of the province, through [illegible] the

unknown. Nevertheless, it seems probable that the earlier period was at least eight or ten times as long as the later one.

DEFORMATION OF THE TERTIARY PENEPLAIN

Although the second peneplain was less perfectly developed than the first, it has been more perfectly preserved, and its attitude can be reconstructed with even greater certainty. The same system of representation has been pursued as in the case of the Cretaceous peneplain, and the deformed surface is represented by contour lines with an interval of 100 feet, and similar qualifications should be made, because as in the case of the contours representing the Cretaceous peneplain. Some parts are only approximately by reason of differences both in degree of baseleveling and also in the quality of maps and other data upon which it is based.

The deformation is somewhat exaggerated, especially in the interior of the province, for the gradient of the baseleveled valleys has not been taken into account. This gradient varies with the size of the stream, but present knowledge of baselevel conditions is not sufficient to warrant any close estimate as to the altitude of the baselevel [illegible]. Probably the error in determining the altitude of the peneplain at any point is greater than the error introduced by neglecting its gradient.

The contours in plate 6 represent the upwarping of all movements which have taken place in the province since the completion of the Tertiary peneplain, while the contours in plate 5 represent movements which have occurred since the close of the Tertiary period [illegible]; hence the contours of plate 5 represent the deformation expressed in plate 6 plus the deformation occurring between the two periods of baseleveling. The amount of this intermediate deformation or the vertical distance between the two baselevels at any point may be found by subtracting altitudes indicated by the contours on plate 6 from those on plate 5.

The character of the deformation which followed the comparatively long period of Tertiary quiet is far better shown than that which followed the long Cretaceous period. It is much nearer the present than the latter, and the evidence for deciphering its history has not yet been obliterated. Part of the evidence consists of physiographic forms, but the larger portion is found in the sediments deposited around the seaward margin of the province. We are largely indebted to

More recent their interpretation and the determination of their bearing on Appalachian history. The conclusions will be stated briefly without attempting to give the evidence on which they are based, although some of it is contained in a valuable paper.

The earliest event since the close of the Tertiary period of baseleveling consisted first of a depression which allowed the waters of the ocean and the Mississippi embayment to advance toward far beyond their previous margin.* Following this came an elevation of the entire province that again started the streams in a career of great activity, and the sea retreated probably beyond the present shore-line. These broad movements may properly be termed epeirogenic, as they affected the entire province, but in every case the movements were unequal, giving axial lines and producing local or orogenic warping. In the subsidence the greatest depression was along the [illegible] and in the same way in elevation the greatest movement was along the main longitudinal axes. A period of comparative quiescence followed, during which the land stood somewhat higher than at present and much higher than during the Tertiary baseleveling period. It was during this interval that the rivers of the eastern coast carved their broad outer valleys, now almost completely submerged beneath the waters of the Atlantic, and the Mississippi excavated its broad valley from Cairo to the Gulf.

In very recent geologic time these oscillations have been repeated in the same order and with a similar effect. The [illegible] the Columbia sediments were laid down, and emergence to the present position and the recent erosion marks the attainment of the present high level attitude of the land.

DEFORMATIONS OF THE TWO PENEPLAINS

The greatest divergence in altitude between the two is most noticeable in the northern portion of the province. The great pre-Tertiary elevation is somewhat complicated and attains its maximum elevation of 4,000 feet at a point 30 miles northwest of Harrisonburg, Virginia. From this point it descends quite rapidly in all directions, but shows a partial agreement with the axes *C D* and *E F*, plate 3. Toward the west the general coincidence of the two planes cannot be determined, but they appear

* The Lafayette formation, by W J McGee: 12th Ann. Rep. U. S. Geol. Survey, 1890–91, pt. 1, pp. 353–521.

to be within 200 feet of each other in the vicinity of West Union, . . . miles east of Parkersburg, West Virginia. On the southern margin of the province the upper peneplain is completely obliterated, but the two probably coincide in the vicinity of Richmond, Virginia. Along the axis the uplift was much less rapid. On the Tennessee line the uplift probably did not exceed 1,200 feet, while toward the southwest, along the axis *E F* (plate 5), it extended certainly as far as the Tennessee river. South of this line the uplifts were much more pronounced and distributed over a broad area, so that their general effect has been to produce a broad fold extending from Greenville, South Carolina, to Knoxville, Tennessee, and with an altitude not exceeding 1,000 feet. In this broad uplift can be traced several local orogenic disturbances, of which the uplift along the axis *C D* is quite prominent, but the greatest elevation occurred along the axis *G H* (plate 5). Many minor folds both of elevation and depression can be distinguished in this region, but their meanings are as yet obscure and we only know that they are not mainly associated with the general warping of the surface of the province. In the vicinity of Atlanta the two baselevels are so near the same altitude that their planes cannot be discriminated, and the same is true along the axis northward as far as Asheville. In the upper portion of the French Broad basin only one baselevel has been detected and this is ascribed to Cretaceous time. The streams have, however, barely sunk their channels through the mantle of disintegrated rock, although the present baselevel of the region renders them extremely active. Westward from Asheville the two baselevels converge under the influence of an uplift along the axis *G H* and both outcrops of the two corresponding peneplains are crossed along the lower course of the French Broad river.

DISSECTION OF THE TERTIARY PENEPLAIN

By far the larger part of the erosion of the Tertiary peneplain was accomplished during the period of stable level which preceded the Columbia depression. The streams were greatly stimulated, and when the elevation was considerable they cut deep gorges along their lower courses, giving rise to the numerous gorges and broad upland rivers so characteristic of the Atlantic coast. The distance these gorges were cut backward toward the interior varies greatly, depending upon the elevation of the land and the char-

Part 2: Interpretation of Geologic Maps

Exercise 5: Topographic Maps and Profiles

Exercise 6: Geologic Maps and Cross Sections

Exercise 7: Geologic Time and Stratigraphy

[illegible]

of the sediments derived from the waste of the land during the interval and deposited as a fringe around its margin.

That the conclusions reached by these three methods of investigation should agree is, in fact, [illegible] them may be [illegible] the [illegible] which [illegible] has been [illegible] reached can be verified by the study of the drainage [illegible] the

CYCLES OF DRAINAGE DEVELOPMENT.

The evolution of the drainage [illegible] began with the [illegible] of [illegible] from the sea and the consequent increase of the eastern continental area toward the west. This process of emergence is believed to have begun [illegible] of the earliest [illegible]. The character of the drainage is much better known [illegible] the final emergence [illegible] during Paleozoic times [illegible] can be traced [illegible] because [illegible] are better [illegible], and hence the history of drainage development which can be read with any degree of certainty may be considered as beginning [illegible]. The development has not been a continuous process, but has been [illegible] for long periods almost [illegible]. The recurrence of [illegible] in the history of a river may be termed cycles of drainage development. First comes a general elevation of the drainage basin, by which the stream is rejuvenated. [illegible] the course of [illegible]. This is followed by [illegible] and the cycle of events is repeated.

Two such cycles are represented [illegible] accompanying [illegible]. The [illegible] show the [illegible] of the [illegible] with the [illegible] the slow process of [illegible] and the more rapid process of [illegible]. The [illegible] are [illegible] of the periods which constitute a cycle. The first of these cycles was extremely long, reaching from the final emergence of the west [illegible] to [illegible] close of the [illegible] period. It [illegible] the most extensive period of [illegible] known to have affected this

region. The second cycle was much shorter, but the [illegible] was sufficient [illegible] the warping of the Cretaceous peneplain and reduction of considerable portions of its surface to a second base-level. The [illegible] has [illegible] entered upon the third cycle, [illegible] [illegible] [illegible] process of [illegible].

CHANGES IN DRAINAGE

Our knowledge of the physiography of the Appalachian province prior to the beginning of the cycle [illegible] is necessarily vague, but the conditions which then prevailed are so intimately connected with the subsequent changes, having determined the positions of the ancestors of the present streams, that they should briefly be considered. As far back as the history of the province can be traced, from near the beginning of Paleozoic time, a great land area existed to the eastward of the present Appalachian [illegible]. How far this land extended eastward is not known with any certainty, but it probably reached [illegible] well beyond the present Atlantic coast line. The [illegible] [illegible] Appalachian valley was [illegible] to this old continent. It has been generally supposed that the folding of the region and its elevation above sea occurred [illegible] at the close of the [illegible]. [illegible], however, afford ground for the theory that folding occurred at various times during the Paleozoic, and that during each of these periods of folding the land area [illegible] by [illegible] and the [illegible] of the [illegible] was pushed farther and farther westward.

Draining the [illegible] westward from the [illegible] of the continent [illegible] in the [illegible] Appalachian province [illegible] [illegible] the land [illegible] spread [illegible] of the [illegible]. These rivers were [illegible] their [illegible] of the present [illegible] may have persisted in [illegible] to the present. The effect upon these [illegible] of the [illegible] was probably less marked [illegible] in the southern portion of the province [illegible] Virginia [illegible] drainage was westward [illegible] what stream or streams is not known. From [illegible] of [illegible] of Paleozoic sediments [illegible] the [illegible] province was raised above sea [illegible] Virginia and New [illegible] the same [illegible].

[illegible]

[illegible]

1.13 Many small (unspecified) perturbations diverge slowly

Author Name

Abstract text.

[illegible]

3.1 [illegible]

[illegible] was able to keep pace [illegible] course [illegible] to [illegible]. The [illegible] was [illegible] to keep [illegible] and [illegible] the under-lying [illegible] and [illegible] formations.

The westward flowing streams [illegible] the [illegible] lower [illegible] about the [illegible] of Black river and [illegible] the [illegible] the [illegible] by [illegible] of all the Mississippi [illegible]. [illegible] lower [illegible] river was [illegible] west [illegible] backward were able to [illegible] course.

After a [illegible] short period of [illegible] was [illegible] the [illegible] formed [illegible] the [illegible] of the [illegible] beyond the scope of this paper. [illegible] Mere [illegible] of the [illegible] plateau [illegible] regions [illegible] already described in Part [illegible].

SUMMARY OF THE [illegible]

It is seen from the foregoing that the present course of the Tennessee river [illegible] and [illegible] the [illegible] Paleozoic [illegible] of the various [illegible] the [illegible] has passed [illegible] found in other [illegible]

[illegible]

CHAPTER III. MACADAMIZED ROADS.

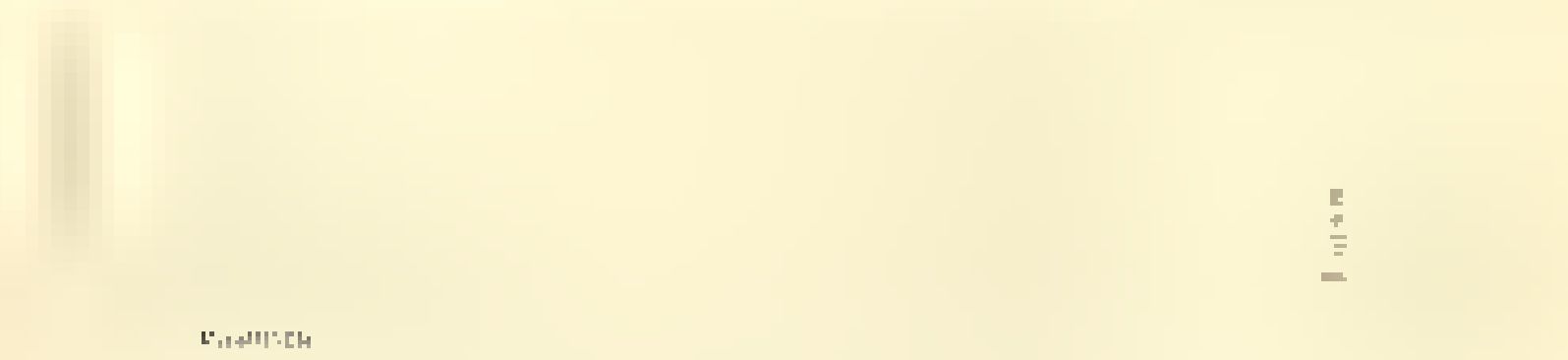
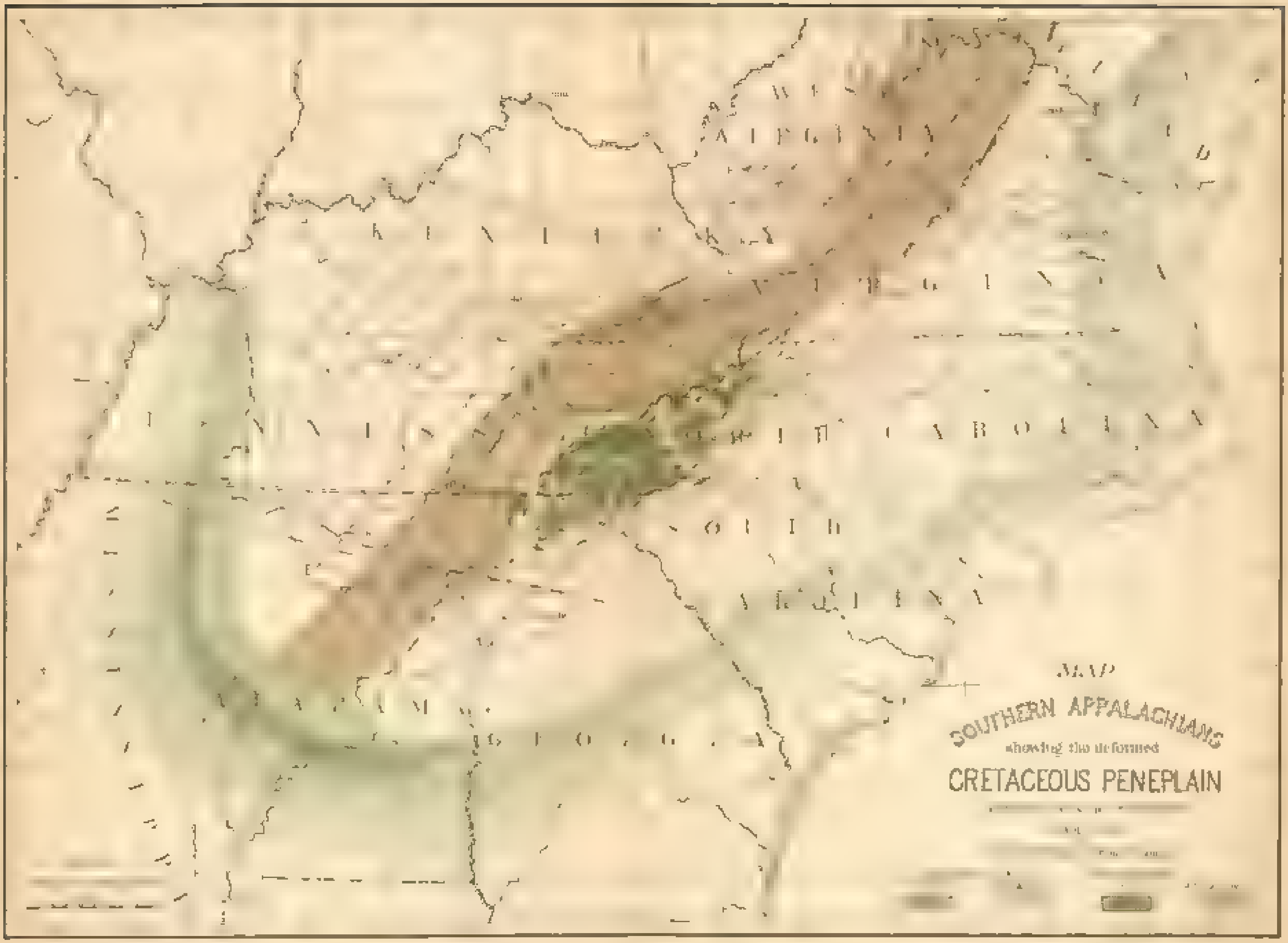
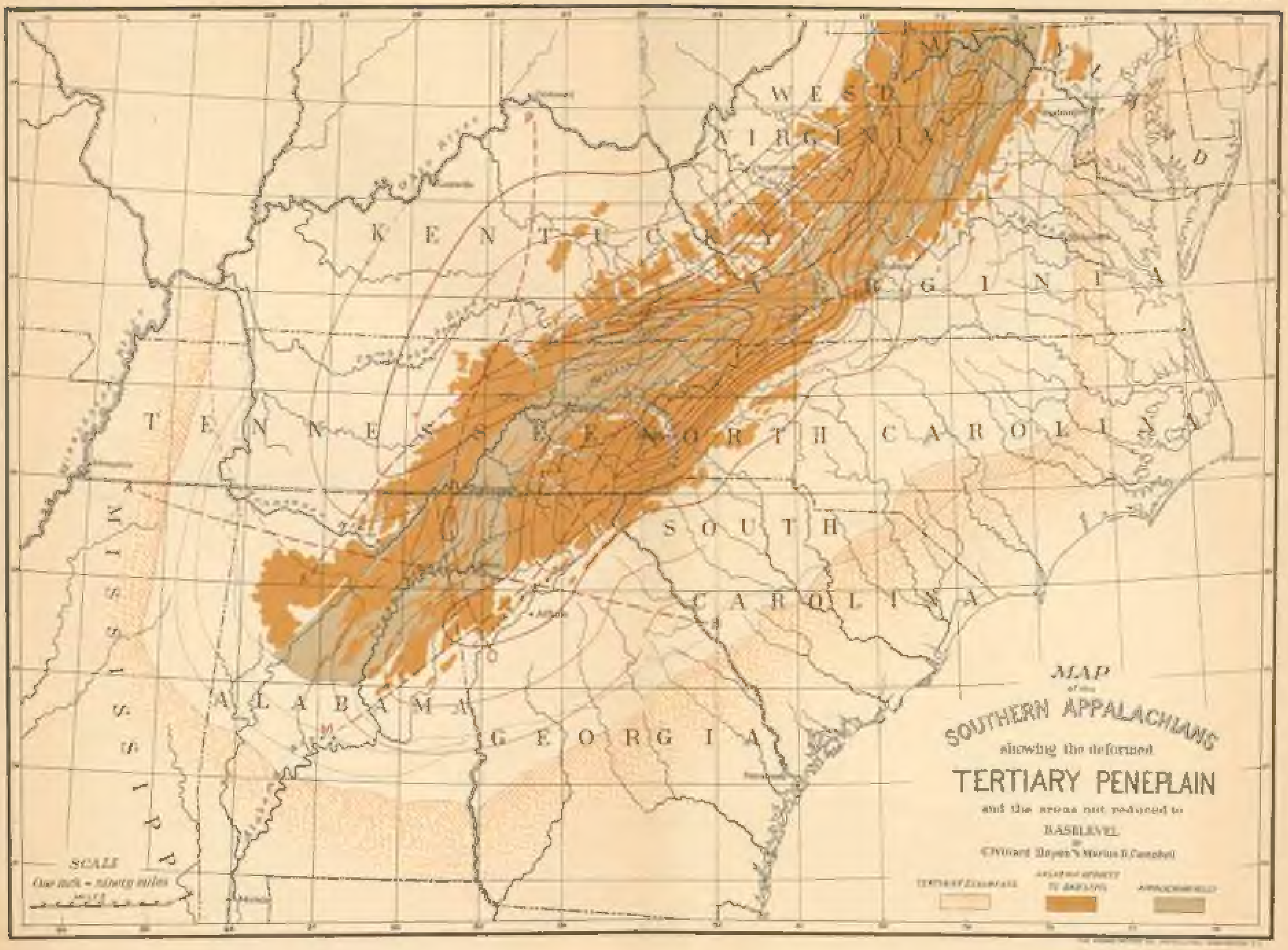


Figure 1.—Photograph of a thin section of a sandstone showing the presence of detrital grains and authigenic cement.


MAP
SOUTHERN APPALACHIANS
showing the deformed
CRETACEOUS PENEPLAIN


W E S T
V I R G I N I A
K E N T U C K Y
V I R G I N I A
T E N N E S S E E
N O R T H C A R O L I N A
S O U T H
C A R O L I N A
A L A B A M A
G E O R G I A
MAP
of the
SOUTHERN APPALACHIANS
showing the deformed
TERTIARY PENEPLAIN
and the areas not reduced to
BASELEVEL
by
©Willard Rouse Berry & Marius R Campbell
SCALE
One inch = ninety miles